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MONEY VERSUS PAIN: EXPERIMENTAL STUDY OF A CONFLICT IN HUMANS

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Ten healthy human males volunteered to be subjects in an experiment in which they were to be paid to endure a painful sensation. This sensation was produced by isometric muscular contraction in the thighs. For each of six sessions the subjects received either a payment that was changed for each session (0.2, 0.5, 1.25, 3.125, 7.8125 French francs per 20 s) or a lump sum. At the beginning of a session, the subjects assumed a seated position against a wall, but without a seat, and the duration for which they could hold this position was the chief variable measured. Heart rate, blood pressure, and magnitude estimation of pain were also recorded periodically throughout each session. Pain was reported after a mean delay of 15 ± 7 s (*SE*), and the magnitude estimates then increased linearly with time. The duration of maintaining the painful position increased linearly in relation to the logarithm of the increase in the amount of payment. Thus, utility of money decreased when pitted against pain.

Key words: conflict, pain, money, motivation, utility, humans

Everyday life entails interacting with numerous alternatives for action (McFarland & Sibly, 1975), and often an individual must choose among conflicting alternatives. In ethology, for example, one basic postulate has been that an animal constantly ranks its conflicting motivations so as to satisfy the most urgent (Baerends, 1956; Tinbergen, 1950). Such conflict has been studied mostly in animals. When studied in humans, typically it has been within the theoretical context of decision-making and game theory involving risk-taking (Bernouilli, 1738; Einhorn & Hogarth, 1981; Mosteller & Nogee, 1951). There have been a few studies, however, of experimental conflict in humans. In these studies, subjects could (a) buy palatable food at the expense of money (Durrant, 1981), (b) earn money by sitting in a cold chamber (Johnson & Cabanac, 1983), (c) or escape thermal discomfort at the expense of fatigue, and vice versa (Cabanac & LeBlanc, 1983). In general, it has been found that subjects traded off these alternatives against each other and tended to maximize their sensory pleasure. In the present experiment, subjects could earn money at the expense of increasing pain. Thus, pain and money were pitted against each other. Money has the advantage of being parametrically quantifiable. Although the main aim was to verify the common-sense expectation that the subjects would increase the duration of pain for increasing reward, the procedure used here was different from those of previous studies, and provided additional information. Also, the kind of pain used was new: isometric muscular contraction. Its intensity was evaluated on a magnitude scale by the subjects, thus permitting comparison with money.

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METHOD

Subjects

Ten male students with mean age of 20.9 ± 0.8 (*SE*) years volunteered to serve as subjects and gave their consent after being thoroughly informed of the protocol (see Appendix). Each subject was also informed that he could interrupt the session and withdraw from the experiment at any time, this being a routine procedure in an experiment involving pain. The subjects were in good health; none of them smoked or had taken any analgesic substance during the period of the experiment, and none was specially trained for physical exercise.

Apparatus

An electric chronometer was used to record the duration of each session. A meter with a

Table 1

Order of presentation, for each subject, of the five different amounts of money paid per 20 s of a session in which pain was tolerated.

Subjects	Reward (FF/20 s)				
	0.2	0.5	1.25	3.125	7.81
YR	1	2	3	4	5
DR	2	1	5	3	4
CL	3	4	1	5	2
OJ	4	5	2	1	3
PB	5	3	4	2	1
PC	5	4	3	2	1
TL	4	3	5	1	2
EB	2	5	1	4	3
CS	3	1	2	5	4
PD	1	2	4	3	5

dial and needle was placed in front of the subject. The needle moved from zero to a given point in 20 s, flicked back to zero, and started again. Unseen by the subject, the number of deflections of the needle was recorded on a counter. The subject could stop the session by dropping onto a thick cushion; this action cut an infrared beam, stopping the needle, the counter, and all the recordings.

Procedure

At the start of the experiment, the subject was instructed as in the Appendix. The painful condition was produced by isometric contraction in the muscles of the thighs (Parsons, 1965). In order to obtain reproducible stimulation, the subject, wearing only swimming trunks, was placed in the sitting position against a wall but without a seat. His lower limb joints were held at right angles at the knees and his bare feet were placed on a rubber carpet to prevent slipping. The pain thus aroused in the extensor muscles of the thighs was comparable to that of tourniquet ischemia plus exercise (Smith, Egbert, Markowitz, Mosteller, & Beecher, 1966), with the important difference that the stimulus here was strictly physiological and harmless (i.e., no tourniquet was used). The subject was informed that he would earn the reward for that day as many times as the needle deflected while he remained in the sitting position against the wall.

Pain was described by magnitude estimation. The subject was instructed to be attentive to his muscular sensation as soon as he took up the sitting position against the wall, and to rate as 1 the first pain perceived. Succeeding estimates were to be rated parametrically as multiples of this anchor. The session ended automatically when the subject let himself drop onto the cushion, cutting the infrared beam as he dropped. In order to prevent the influence of fatigue, the sessions were separated by 3 or 4 days. The sessions were held at the same time of the day in order to avoid nychthemeral drift of pain perception (Hildebrandt & Pöllmann, 1973).

Measurements and Statistics

For each session, the main measurement was the duration of that trial. In addition, the following variables were recorded at time zero with the subject standing at rest near the wall, then at 30 s, 1 min, and, thereafter, every minute from the time the subject assumed the sitting position until he ended the session: estimate of the pain; heart rate, measured from an electrokymograph (EKG) in interspike intervals (QRS waves) and displayed digitally every two beats; and arterial blood pressure, measured and recorded every minute using a noninvasive, indirect, automatic monitor.

All results are presented as means ± *SE*. When appropriate, Student's *t* or coupled *t* tests were used. The significance of differences between more than two means was determined by an analysis of variance and the Duncan multiple range test ($p < .05$).

Reward

Each subject received 10 French francs (FF) for his participation in each session. Additional income was possible, varying in relation to the subject's responses in each of the six

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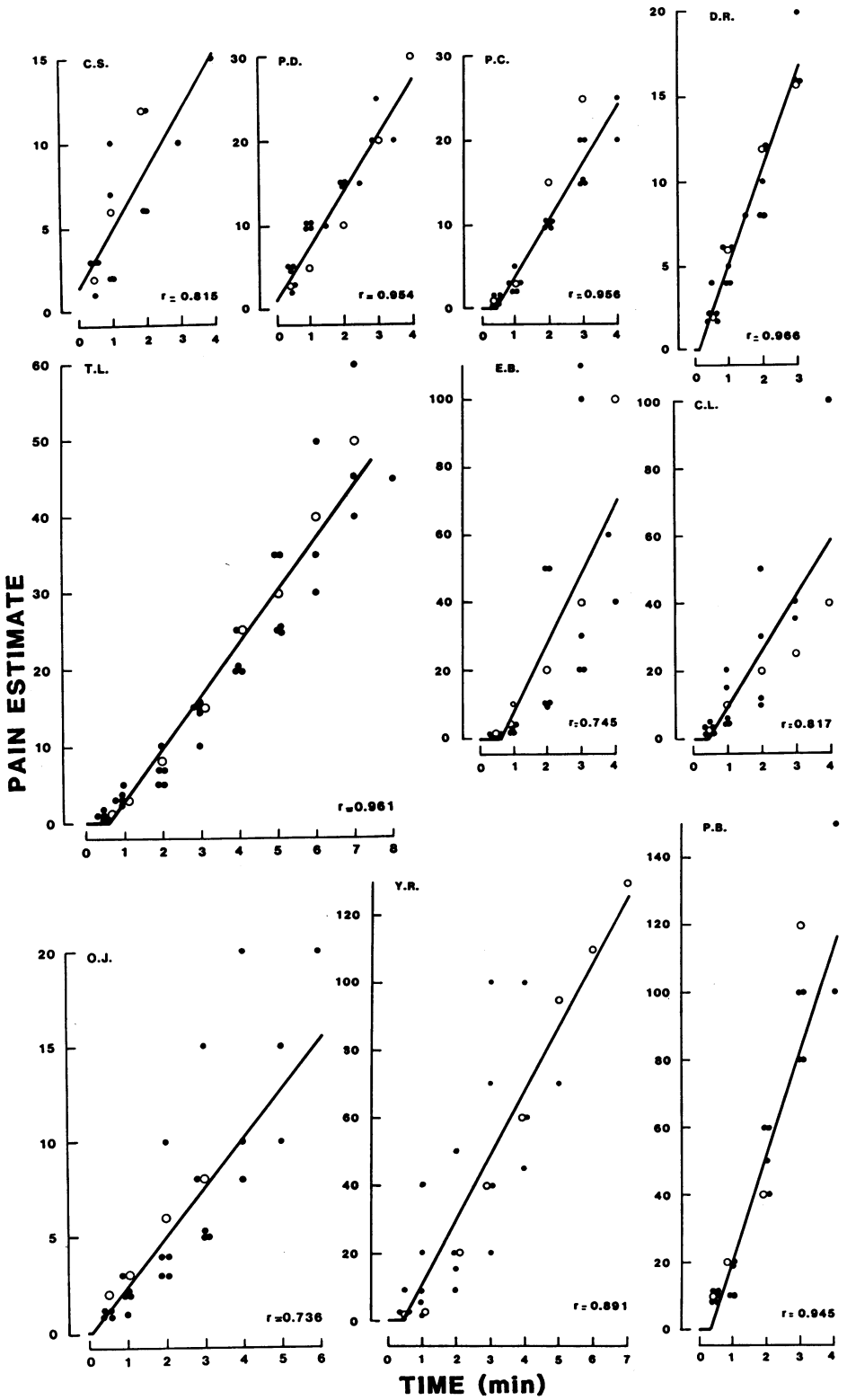
Fig. 1. Pain magnitude ratings given by individual subjects, as a function of time during the six sessions. Open circles indicate the effect of the highest amount of money given. The subject's initials are shown in the upper left corner of each rectangle, and the correlation coefficient, *r*, is shown in the lower right corner. The regression lines were obtained by the method of least squares.


C.S.
r = 0.815
P.D.
r = 0.954
P.C.
r = 0.956
D.R.
r = 0.966
T.L.
r = 0.961
E.B.
r = 0.745
C.L.
r = 0.817
O.J.
r = 0.736
Y.R.
r = 0.891
P.B.
r = 0.945
PAIN ESTIMATE
TIME (min)

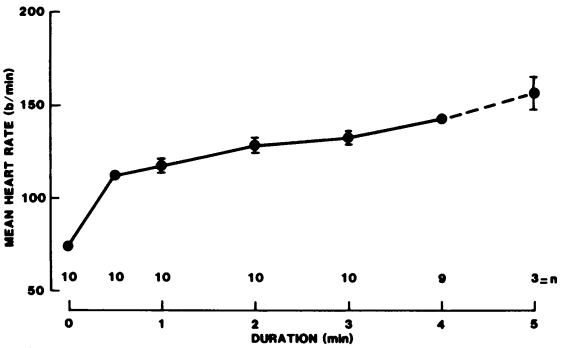


Fig. 2. Mean heart rate (±*SE*) during the sessions, as a function of time (*n* is indicated in the figure). Individual subjects' data are given in Table 2.

sessions for each subject. The first session was presented as training for the estimation procedure and each subject received an additional 10 FF. In the five subsequent sessions, the subjects received varying payments. In a previous study (Johnson & Cabanac, 1983), the knowledge of cumulative income was observed to influence subjects' behavior. In order to avoid this, the reward was earned by units of time. The rewards per 20 s for the five sessions were 0.2, 0.5, 1.25, 3.125, and 7.81 FF. For each subject, these conditions were presented in a different order, determined by a Latin square design as shown in Table 1.

RESULTS

Estimates of Pain Magnitude

Pain was not reported when the subjects first assumed the sitting position. Once the threshold for reporting pain was passed, the estimates increased linearly with time. The estimates given by each subject in the various sessions differed little from one session to another. Figure 1 shows the total estimates of the six sessions given by the subjects. The estimates obtained during the session with the highest reward are shown separately, by open circles. Mean regression coefficient of estimates plotted against time was 0.878 ± 0.029. The mean intersection of individual regression lines with the duration axis was 15 ± 6.5 s; the intersection of the mean regression line with the duration axis was 23.1 s.

Physiological Responses

Two variables, heart rate and arterial blood pressure, were measured as indices of physiological strain. Heart rate increased from 74.2 ± 3.1 recorded at zero time, to 111.8 ±

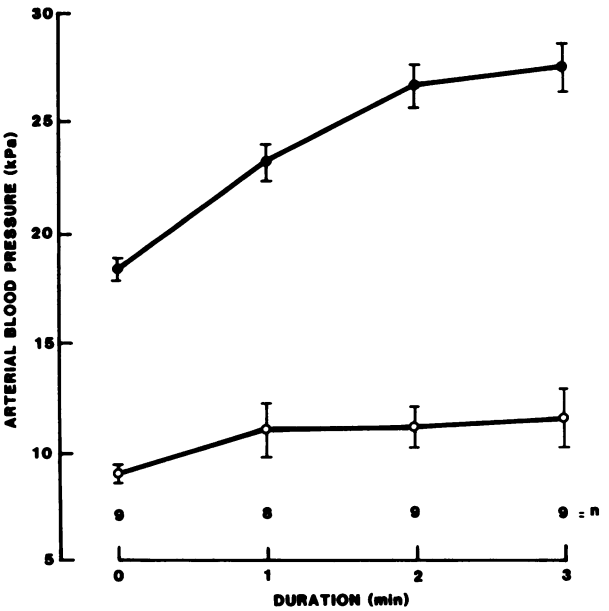


Fig. 3. Mean diastolic (lower curve) and systolic (upper curve) blood pressure for the group of subjects during the sessions. Vertical lines indicate standard errors. Baseline value is given at zero time just before the painful posture was assumed. *n* is the number of subjects. Individual subjects' data are given in Table 3.

Table 2

Mean heart rate (and standard error) of each subject in successive periods of a session. Absence of a parenthetical number indicates that only one value was recorded.

Subjects	Time (min)						
	0	0.5	1	2	3	4	5
YR	73 (4)	133 (5)	148 (3)	155 (2)	157 (3)	164 (4)	171 (2)
DR	77 (4)	106 (2)	114 (4)	126 (5)	134 (6)		
CL	94 (3)	122 (3)	129 (5)	146 (2)	150 (2)	158 (5)	
OJ	72 (4)	121 (3)	125 (4)	127 (5)	127 (4)	149 (2)	159 (4)
PB	78 (3)	104 (3)	110 (2)	121 (3)	129 (5)	128 (5)	
PC	84 (6)	113 (4)	116 (5)	128 (6)	132 (6)	151	
TL	64 (2)	101 (5)	108 (5)	122 (6)	124 (7)	132 (6)	139 (5)
EB	60 (3)	97 (6)	108 (4)	113 (9)	129 (13)	125 (3)	
CS	70 (5)	111 (4)	113 (7)	129 (4)	125	142	
PD	71 (3)	112 (4)	103 (5)	112 (4)	116 (4)		

Table 3

Systolic (S) and diastolic (D) blood pressure (kPa) for each subject as a function of within-session time. The data are the mean values computed across sessions and standard error is given in parentheses. When there is no parenthesis, only one value was recorded.

Subjects		Time (min)			
		0	1	2	3
DR	S	19 (1)	25 (1)	29 (5)	28
	D	9 (1)	13 (1)	14 (0)	15
CL	S	17 (0)	19 (1)	24 (1)	23 (4)
	D	11 (1)	13 (0)	14 (1)	11 (2)
OJ	S	17 (0)		32 (3)	29 (0)
	D	8 (1)		11 (5)	13 (0)
PB	S	20 (1)	26 (2)	27 (2)	28
	D	9 (0)	10 (1)	11 (2)	12
PC	S	17 (0)	21 (1)	23 (1)	22 (0)
	D	10 (1)	13 (0)	11 (1)	16 (0)
TL	S	17 (0)	21 (1)	27 (3)	27 (2)
	D	9 (1)	9 (2)	8 (2)	7 (2)
EB	S	18 (1)	23 (1)	27 (2)	31 (6)
	D	9 (1)	12 (1)	12 (1)	14
CS	S	20 (0)	24 (1)	24 (2)	31
	D	7 (1)	3 (1)	6 (3)	7
PD	S	18 (0)	23 (1)	24 (1)	25 (2)
	D	7 (1)	12 (1)	13 (1)	7

3.4 at 30 s; it then increased at a lesser but almost linear rate with time (Figure 2 and Table 2). Both mean systolic and diastolic blood pressure increased with time (Figure 3 and Table 3). Systolic pressure increased monotonically from 18.1 ± 0.5 kPa at time zero, to 27.0 ± 1.1 kPa at minute 3. Figure 3 presents only the results obtained during the first 3 min; at minute 4 only five series of readings were obtained because most subjects had by then interrupted the sessions. Diastolic pressure increased also, from a baseline value of 8.6 ± 0.4 kPa to 11.7 ± 1.2 kPa after 1 min; it then leveled off and did not significantly change thereafter.

Duration Tolerated

When only the preestablished fixed payment was given, the subjects tolerated the painful posture for a mean duration of 4 ± 0.4 min. When the reward was varied, the duration of the sessions increased as a function of the amount of reward per 20 s of participation. Figure 4 (left panel) shows this relation, and Table 4 gives individual data. The duration tolerated first increased rapidly, then more slowly with increasing amounts of rewards. This relation is also shown logarithmically, which gives a linear relationship. The correlation coefficient of duration versus log reward was 0.989.

DISCUSSION

The factors that determine the extent to which humans tolerate pain are not yet well understood. The present study suggests that manipulation of the reinforcing consequences of such toleration provides a promising method for further investigation of such phenomena. Moreover, the method employed here to produce the painful stimulus would seem to provide a safe, humane, and ethical means of investigating the phenomena associated with pain. The present results cast some light on the painful stimulus experimentally used here for the first time and on its physiological and psychological effects, as well as indicating how the conflict was resolved when this painful stimulus was pitted against the money that was being earned.

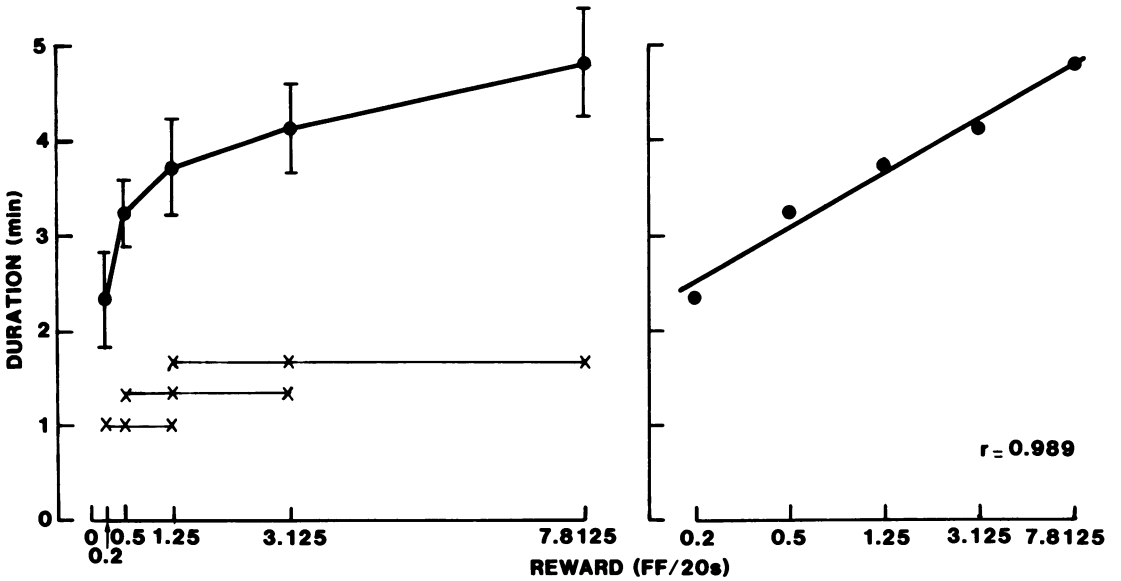


Fig. 4. Mean duration and standard error (vertical lines) of increasing pain toleration, as a function of the amount of money earned per 20 s, shown on a linear scale (left) and on a logarithmic scale (right). r is the linear regression coefficient of the data. In the left graph, means not underlined by the same line (x——x) are significantly different ($p < .05$).

Tourniquet ischemia has been widely used as a pain stimulus in humans. This method is considered reliable by some authors (Sicuteri, Franchi, & Michelacci, 1974; Sternbach, Murphy, Timmermans, Greenhoot, & Akeson, 1974) but is judged unreliable by others (Wolff, 1978) for human psychophysical pain measurements. The method used here to produce pain was similar to tourniquet ischemia, with the important difference that it is harmless because it results from strictly physiological processes. This point is important from an ethical point of view (Sternbach, 1979). The isometric muscular contraction was used to explore pain tolerance defined as the highest level of experimental pain accepted by the volunteer. Tolerance is considered to be the most sensitive pain-response parameter in human studies (Wolff, 1980; Wolff, Kantor, & Cohen, 1976). In addition, this stimulus occasioned reproducible estimates on a magnitude-estimation scale proportional to the duration of the stimulus (Figure 1). This was quite interesting in view of the fact that the stimulus was natural and harmless, and favors this method for future experimental studies of pain in human subjects. As is often the case with pain, however, the method has a limitation—namely, the physical magnitude of the stimulus is not available and therefore it is impossible to plot behavioral measures directly against the stimulus dimension. Finally, isometric muscle contraction produced tachycardia and hypertension (Figures 2 and 3), all indicative of activation of the sympathetic nervous system (Kahn & Monod, 1984). Similar findings have been obtained when pain was induced by local exposure to cold (LeBlanc, 1975).

In a previous experiment, Johnson and Cabanac (1983) found that the duration of stay in an uncomfortable cold chamber increased

Table 4

Duration (min) for which the painful stimulus was tolerated by each subject, in relation to the reward being given every 20 s during the period of toleration.

Subjects	Reward (FF/20 s)				
	0.2	0.5	1.25	3.125	7.81
YR	3	4.3	2.3	5	7
DR	2	3	2	3	3
CL	1.7	2	4	2.3	4.8
OJ	2.3	3.5	5.5	4.7	6
PB	0.2	3.8	3	4	3.3
PC	3	3	3.7	4.7	3.8
TL	5.5	5.8	7	7.6	8.3
EB	3.8	3.1	4	3.8	4.5
CS	1.5	1.7	2.3	2.8	2.8
PD	2.3	2.5	3.4	3.8	4.5

with the logarithm of the amount of reward. However, the duration of cold tolerated also correlated well with a more complex correlate of money earned: rate of reward against accumulated earnings, the latter being the information available to the subjects. The present experiment avoided the ambiguity introduced by accumulated earnings. The information given to the subjects consisted only of the amount of money in the particular unit of time. Interestingly, under these conditions the subjects always waited for the meter to indicate the end of a time unit before interrupting the session. These results confirm that the duration of toleration of unpleasant pain correlated with the logarithm of the rate of reward (Figure 4). This is quite in accordance with the answers given by human subjects to questionnaires about the desirability of money (Galanter, quoted by Stevens, 1959). The desirability of money was found to follow a power law with an exponent equal to 0.5. The present results confirm that, within the range explored, money had a decreasing utility. This was first stated by Bernouilli (1738) as a postulate. It is an interesting extension to money itself of the economic law describing the diminishing marginal rate of substitution (Lipsey, Steiner, & Purvis, 1984).

Figure 4 shows that even for negligible amounts of reward the subjects remained in the sitting posture for more than 2 min, a duration well above the threshold for reporting pain (15 to 20 s). The same phenomenon was also observed when subjects were placed in a situation of conflict between cold discomfort and money (Johnson & Cabanac, 1983). In that experiment, too, the subjects remained in the cold chamber for more than 20 min even when reward was the lowest rate provided in the experiment.

When individuals are presented two mutually exclusive conditions of reward, an approach-approach conflict is usually postulated where the two rewards combine and result in an indifference curve where the two utilities are equal (Thurstone, 1931). The preference is assumed to relate to the subject's position regarding the indifference line. The approach-avoidance situation studied here may be considered in the same way. The increasing durations of trials with increasing amounts of reward, observed here with pain and elsewhere with cold discomfort (Johnson & Cabanac, 1983), suggest that the subjects terminated the sessions when the discomfort associated with pain exceeded the effect of the monetary reward in sustaining the behavior in question. Interestingly, while pain increased linearly with time, the effect of money reward increased only logarithmically.

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APPENDIX

INSTRUCTIONS TO THE SUBJECTS
(Translated from the original in French)

1. The aim of this experiment is to study the relationship between pain tolerance and motivation. You will be exposed to a physiological pain: ischemia during isometric muscular contraction, and you will be rewarded with money at a variable rate. Pain will be produced in your quadriceps by maintaining the seated position at a square angle against a wall, without a seat.
2. During the sessions, you will be dressed in a pair of bathing trunks and you will be barefooted.
3. *Your aim must be to remain seated as long as you consider it worthwhile for your reward.* Since the session stops when you think it hurts too much, there is no risk of damage for you. To end the session you just let yourself drop down on the cushion.
4. When you have started the series, it is important that you participate in all 6 sessions but you are entitled to end the experiment at any time. The total reward for all the experiment is reasonable. In addition to the money earned in any session you will receive 10 FF for each session (preparation time, etc.). The rate of the reward will be varied from session to session. You will not know it beforehand, but will discover it as soon as you start the sessions.
5. The first session will be rewarded with a lump sum of 20 FF. In this session you will learn to rate pain quantitatively. You will be asked periodically to rate your pain. When you feel pain for the first time, rate it 1. Then rate the following pain by comparing with this 1. If it hurts twice as much, rate 2; if it hurts 100 times more, rate 100, etc. Your heart rate and blood pressure will be monitored also.
6. Do not speak about the experiment to other subjects or outside the laboratory until all the experiment has been completed.

Approved, date Signature: